SUGGESTIONS CONCERNING DR. C. G. ABBOT'S PROGRAM FOR FOUR WORLD OBSERVATORIES FOR THE OBSERVATION OF EXTRATERRESTRIAL SOLAR RADIATION.

By C. DORNO.

[Davos, Switzerland, May 21, 1920.]

SYNOPSIS.

The scientific and practical importance of the above program is emphasized. On account of the inadequacy of existing meteorological records, special observations, including detailed cloud records, are necessary before sites for solar observatories are finally decided upon. To obtain these cloud records an instrument which has been employed at the Davos observatory since October, 1919, for recording the illumination of a horizontal surface by the sun and sky may be utilized.

Since, at night, the radiation to the sky varies with zenith distance but not with azimuth, it becomes possible to use for the measurements a blackened hollow sphere as an absolute black body, such as Ångström's "Tulipan." This seems to meet Abbot's objection that the absorption of blackened surfaces for wave lengths greater than 15 μ is not well known, and, in consequence, measurements by instruments like Ångström's pyrgeometer contain an unknown error. Comparisons between the pyrgeometer and the Tulipan, however, show a reasonably constant ratio.

The importance of ascertaining the ozone content of the atmosphere is emphasized, and it is pointed out that photoelectric intensity measurements with the cadmium cell of the spectrally decomposed ultraviolet radiation may help to solve this difficult problem.

It is suggested that for investigations in the infra-red bacteria may be used in place of photographic plates. Also, that Ångström's nocturnal radiation measurements of 1913 should be repeated in optically undisturbed times.—*H. H. K.*

Dr. Abbot has developed an extensive program for continuous observation of the variations of extra-terrestrial solar radiation and their relation to the meteorology and climatology of the earth,[1] the scientific and practical importance of which can hardly be overestimated. At four most favorable, widely separated points, these observations are to be carried on according to Dr. Abbot's methods, which have been proved long since, and have been amplified by some new points of view; the results of the observations are immediately to be made known to the world at large by wireless telegraphy, and thus at once to be made available for meteorology and geophysics. Having had experience for more than 15 years in high mountains in continuous observation of the annual course of solar radiation, I may, perhaps, be allowed to make some suggestions regarding this fundamental program.

First. Abbot rightly insists on the fact that the places for observation must be chosen with the utmost care and that the present meteorological data, especially on cloudiness, is not sufficient for decisive conclusions. It is therefore necessary to begin with careful observations of the cloudiness at the places in question. Abbot gives a description of a relatively simple instrument for registering the cloudiness photographically. At intervals of a quarter of an hour the instrument photographs the sky, which is reflected upward by a sphere.

Perhaps an instrument, which since October, 1919, has been in continuous use at the Davos observatory, and which also serves other purposes, may offer greater accuracy. It registers permanently the illumination of the horizontal surface by the sun plus the sky, and is based on the photoelectric principle. A highly evacuated potassium cell is horizontally exposed under a well-chosen filter and a dense plate of milk-glass, which diffuses the incident rays, in a case which shelters it against precipitation and disturbances of isolation; the photocurrent which is conducted through a mirror-galvanometer is photographically registered. Thus, it was experimentally made possible—not without much effort—to find a combination of cell, filter (Schott F 5899)[2] and milk-glass, that offers a curve, which, through all the variations of cloudiness, brightness, and altitude of the sun, comes satisfactorily near the physiological brightness curve that acts upon the human eye. The normal curves, resulting from regular observation series carried on for many years,[3] together with very numerous comparable photometric measurements, furnish the authority for this statement.

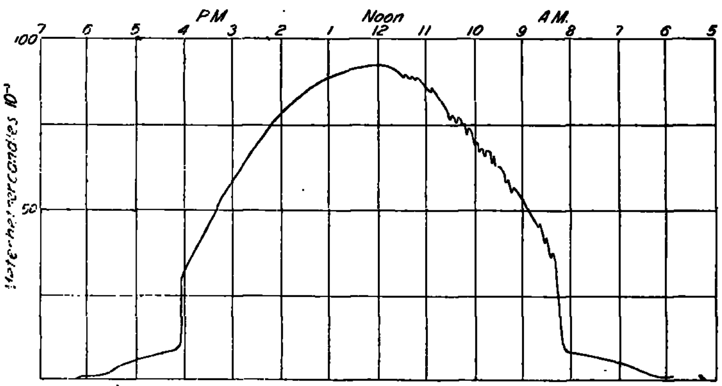

FIG. 1.—Total illumination on a horizontal surface at Davos, Mar. 4, 1920. (True solar time.)

The least vestige of light vapor from the valley, for instance, occasional streaks of smoke from the neighboring health resort, cumuli rising in the sky, or even the slightest trace of cirri occurring in the neighborhood of the sun, find their distinct expression in the curves.

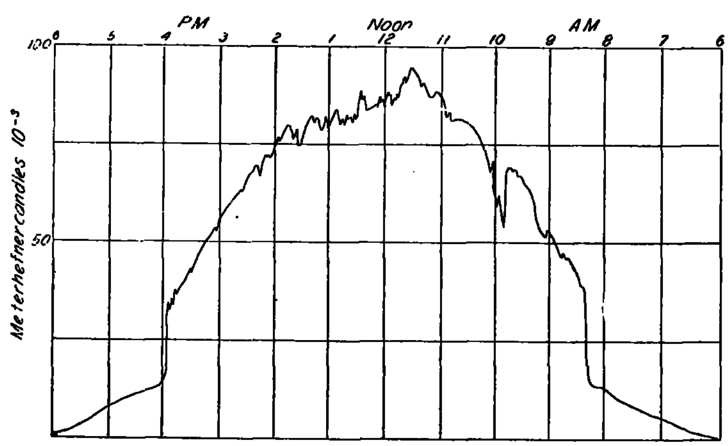

FIG. 2.—Total illumination on a horizontal surface at Davos, Mar. 3, 1920. (True solar time.)

An original curve of March 4, 1920, of a perfectly cloudless day, on which, in the forenoon, some vapor from the valley rose to the height of the observatory, and that of March 3, 1920, when the degree of solar brightness oscillated between S_3 and S_4 on account of very light, changing, high sheet of clouds, cloudiness degree B_{3-5}, are shown by figures 1 and 2. In these curves it is interesting to notice the rapid rise and fall on the appearance of the sun and its disappearance behind a mountain. The monthly numbers set up according to diurnal hours (true solar time) are given in Table 1, first, for all days without distinction, second, for cloudless days.

[1] *Proceedings of the National Academy of Sciences of the United States of America.* Vol. 6, No. 2, February, 1920.
[2] *Physikalische Zeitschrift,* 1917, p. 381.
[3] *Studie über Licht und Luft des Hochgebirges,* Vieweg, 1911.

TABLE 1.—*Monthly means of the illumination of a horizontal surface, by hours.*

[Meterhefnercandles 10^{-3}.]

ALL DAYS.

Month. \ Sun's hour angle.	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	Mean of the days of 24 hours.	Mean maximum.	Abs. maximum.	12h Abs. maximum.	12h Abs. minimum.
1919.																					
October (3d decade only)	.....	.....	.....	5.3	19.3	42.2	53.4	59.6	58.1	49.2	32.8	17.7	5.1	0.2	.....	.....	14.27	80.3	118.5	92.7	31.0
November	.....	.....	.....	1.9	10.0	24.4	34.7	42.3	40.2	35.4	26.9	12.6	3.1	.....	.....	.....	9.65	54.0	86.7	86.7	18.9
December	.....	.....	.....	0.6	5.8	14.6	26.5	33.1	32.9	28.1	19.9	7.9	1.0	.....	.....	.....	7.09	42.7	69.8	62.6	*5.7
1920.																					
January	.....	.....	.....	1.5	8.7	20.3	34.7	41.1	41.1	33.8	22.6	9.5	2.0	.....	.....	.....	8.97	50.4	86.1	62.4	14.7
February	.....	.....	0.6	4.6	15.3	40.1	55.3	64.1	64.7	57.3	44.3	21.5	5.3	0.6	.....	.....	15.57	75.9	102.9	88.2	30.7
March	.....	0.3	5.0	16.9	42.3	60.3	75.4	82.4	85.8	75.1	63.5	45.5	18.2	5.3	0.5	.....	24.02	106.1	149.6	113.9	39.9
April	.....	4.0	17.6	36.5	57.3	73.3	88.3	90.6	81.6	74.9	66.1	52.9	33.0	12.5	3.9	.....	28.85	118.3	163.2	146.2	30.5
May (1st decade only)	1.0	9.0	24.9	45.5	71.5	91.4	92.0	97.3	90.8	83.6	74.2	53.4	37.4	18.8	7.5	1.3	33.32	146.4	158.0	156.4	45.3

CLOUDLESS OR ALMOST CLOUDLESS DAYS.

Month.	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	Mean of the days of 24 hours.	Mean maximum.	No. of days.	12h Abs. maximum.	12h Abs. minimum.
1919.																					
October (3d decade only)	.....	.....	.....	6.0	22.8	51.0	68.3	80.8	81.6	69.4	50.9	25.7	6.6	0.6	.....	.....	19.32	.....	†5	.....	.....
November	.....	.....	.....	1.8	9.8	29.6	49.6	58.1	58.5	49.1	33.3	13.4	2.6	.....	.....	.....	12.74	.....	6	.....	.....
December	.....	.....	.....	0.7	5.0	18.6	37.4	45.5	45.2	37.3	24.0	8.3	1.1	.....	.....	.....	9.29	.....	10	.....	.....
1920.																					
January	.....	.....	.....	1.4	8.7	23.7	44.5	53.3	53.3	44.6	29.2	10.3	1.9	.....	.....	.....	11.29	.....	12	.....	.....
February	.....	.....	0.5	4.1	14.5	42.4	59.3	68.8	69.9	61.9	46.5	23.0	5.0	0.6	.....	.....	16.52	.....	15	.....	.....
March	.....	0.5	5.7	20.0	51.0	73.8	90.2	101.2	101.8	90.7	73.6	54.5	21.5	6.7	1.8	.....	28.88	.....	11	.....	.....
April	.....	4.9	19.8	46.4	75.8	98.9	117.3	125.6	126.2	118.1	95.6	71.2	45.5	16.6	4.2	.....	40.25	.....	3	.....	.....
May (1st decade only)	1.3	11.3	33.1	60.7	87.6	108.9	124.7	136.7	138.9	131.2	114.9	89.5	58.8	25.7	9.4	1.3	47.25	.....	†3	.....	.....

* 23 December (a day of uninterrupted thick snowfall, grown famous on account of the tremendous avalanches that came down on Davos). † Decade.

The only part of the apparatus that is costly is the photographic registry contrivance and the galvanometer, if once rightly constructed and calibrated, it needs for its manipulation only a careful hand, not a highly trained one. According to my experience of many years, highly exhausted cells maintain sufficient constancy, if carefully handled, provided they are not charged too much and not exposed to too intense radiation; the registering apparatus which has been in permanent use here for seven months, proves this anew, for the curves are checking each other constantly. The change is very small, 4 volts in winter, and 2 volts in summer; the intensity is so diminished by the milk glass and the filter, that the deflection of the galvanometer (of sensitiveness 10^{-9} amp.) at a meter distance is 110 mm. at the highest. Among other advantages, this instrument not only registers the cloudiness but records any other opacity of atmosphere, especially the dust content, which, in dry deserts (and in such places, dust seems to be the chief consideration), would be more dangerous to the observations than cloudiness. Disturbances by water vapor would not be less feared, and, for this reason, the tropical countries and especially all small, isolated islands in the ocean should be avoided. Places far distant from the sea, situated on a high plateau, if possible with a perennial snow covering or, at least, one lasting for many months, afford probably the most favorable points for observation, unless the cloudiness too often hinders.

Second. Concerning the absorption by the atmosphere of very long-wave radiation, which is so important for the intensity measurements of terrestrial radiation, Abbot insists on the fact that for the wave-lengths greater than 15μ the absorption of the surface of the instruments in use to-day has not been sufficiently investigated, and that especial importance should be attached to the exact determination of the ozone-content of the air, although there is but little in the lower strata of the atmosphere. There are two reasons for this: First. Ozone is especially absorptive of those wave lengths (about 10μ) which prevail in the terrestrial radiation; second, this absorption band lies outside the absorption bands of water vapor, while the absorption bands of carbon dioxide contained in the atmosphere to a much larger extent than ozone, coincide with those for water vapor.

As far as other investigations have permitted, radiation measurements were carried on at the observatory of Davos in the winter seasons of 1911–1913, the results of which have been added in a preliminary way to a more extensive publication.[4] They have been taken up in a new and more systematic way since the autumn of 1919, and especial importance has been given, first, to the exact determination of the absolute values, and, second, to the proportion of values which K. Ångström's "Tulipan" and "Pyrgeometer" furnish. The integration values of effective radiation (R) through the whole night, from the end of the astronomical evening twilight to the beginning of astronomical morning twilight, measured by Tulipan, the values of computed radiation of a black surface (S), the radiation of the atmosphere of given temperature (E), and of 20° C. (E_{20}) for the nights with the smallest radiation of the atmosphere, are contained in the following table, by months:

TABLE 2.—*Nocturnal radiation measurements, October, 1919–May, 1920.*

[Monthly minima of E_{20}. Integration values of the whole night.]

Date.	Temperature.	Abs. humidity.	R.	S.	E.	E_{20}.
1919.	°*C.*	*g/m.*³	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 30	−10.9	1.27	0.182	0.394	0.212	0.331
Nov. 3	− 8.4	1.58	.178	.409	.231	.347
Dec. 11	−12.2	1.11	.183	.386	.203	.324
1920.						
Jan. 25	− 3.9	1.83	.180	.438	.258	.362
Feb. 8	− 8.2	1.09	.205	.411	.206	.309
Mar. 4	+ 2.0	2.73	.216	.477	.261	.337
Apr. 3	− 4.7	2.10	.174	.433	.259	.369
30	+ 3.2	3.45	.195	.486	.291	
May 6	+ 0.1	2.84	.183	.465	.282	.374

R = Effective Radiation.
S = Computed Radiation of a black surface.
E = Radiation of the atmosphere of given temperature.
E_{20} = Radiation of the atmosphere of 20° C.

[4] *Abhandlungen des Preuss. Meteorolog. Inst.* Bd. VI, 1919.

The adopted radiation constant is $\sigma = 8.35 \times 10^{-11}$ gr. cal. per mm. per sq. centimeter.[5] The E-values are lower than those obtained by interpolation from A. Ångström's "Table for Nocturnal Radiation at Various Altitudes."[6] (For an elevation of 1,600 m. and a temperature of $+12°$ C., $E = 0.33$ cal., $E_{20} = 0.37$ cal.). This seems to indicate an especially dry and pure atmosphere and adds a new proof to the many already existing for the continental character of the climate of the Swiss Eastern Alps Plateau. The ratio $\frac{\text{Tulipan}}{\text{Pyrgeometer}}$, as determined during the months of September, 1919, to May, 1920, on clear nights with changing movement of the air and changing vapor content, which rose frequently in the calmness of the winter night as finest haze hardly visible to the eye, as shown in the following table:

TABLE 3.—*Ratio* $\frac{\textit{Tulipan}}{\textit{Pyrgeometer}}$.

Date.	Sun's hour angle.		Ratio.	Clouds 0–10.	Wind.	Remarks.
1919.	*H. m.*	*H. m.*				
Sept. 24	6 55	8 09	1.21	0–4	C	
Sept. 26	7 02	8 07	1.43	0	S′	
Oct. 4	6 40	8 14	1.37	0	C	
Oct. 10	7 13	8 12	1.39	0	C	
Oct. 18	6 18	8 07	1.52	0	C	≡°
Oct. 30	6 00	7 45	1.37	0	C	
Nov. 28	5 54	7 19	1.32	0	C	
Dec. 2	5 19	6 52	1.39	0	C	
Dec. 11	5 51	7 10	1.47	0	C	V°
1920.						
Jan. 19	5 35	7 48	1.32	0–1	C	
Feb. 5	5 18	7 41	1.37	0	C	
Feb. 18	6 05	8 01	1.48	0	C	Sometimes smoky.
Feb. 25	6 39	8 32	1.29	0	C	
Mar. 1	6 30	7 42	1.39	0	C	
Mar. 22	6 46	7 44	1.40	0	N′	
May 11	8 06	9 07	1.40	0	C	

The gauge factor, introduced in comparative calculation, is that furnished with the Tulipan by the Physical Institute of Upsala and later corrected by means of the Pyrgeometer factor. It proves, as has already been supposed[4] to be much too high. For the present consideration it is important that the ratio Tulipan/Pyrgeometer be, to a satisfactory extent, constant. The variations found by comparing the integration values and single values measured every ten minutes can hardly be expected to be smaller, especially if we consider that it lies in the nature of the Tulipan instrument to be behind hand, that every single drop is formed but slowly, and that it depends on chance whether the measuring takes place immediately before or after the fall of a drop. It will be possible to infer from these comparative measurements whether a sufficient constancy of ratio between the two types of Ångström's instruments does already exist or may be attained by a slight correction. This is very important for two reasons: First, it proves anew that the distribution of radiation over the night sky is much simpler than over the day sky, because, on the whole, the radiation increases from the zenith to the horizon independently of the azimuth, and in close relation to the intensity of the radiation, so that it suffices to measure only a small area near the zenith; second, it enables us to use for the measurement (as K. Ångström does by "Tulipan") a blackened hollow ball as an absolutely dark body, whereby the serious doubt existing on account of the possible loss of the radiation of the wave lengths greater than 15μ, is done away. It is true, the existing Tulipan instrument seems to answer all the requirements relating to this, and it also possesses the great advantage of not being influenced by convection, or at least very little so, and to react but slightly on oscillating air movements.

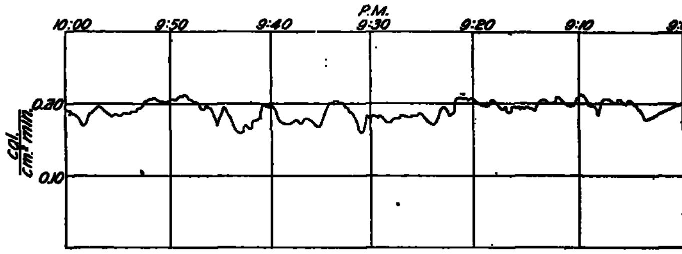

FIG. 3.—Nocturnal (effective) radiation at Davos, Feb. 18, 1920. (True solar time.)

Eliminating the compensation, some continuous registerings have been carried on with the pyrgeometer in Davos during entirely calm winter nights. The thermocurrent generated between the bright and black strips on account of the effective radiation is conducted through a mirror galvanometer and registered. A sector of the curve of February 18 follows:

In spite of the not inconsiderable variations produced chiefly by the descent of cold air from the mountain slopes to the bottom of the valley the nocturnal course of effective radiation is, in this kind of curves, to be recognized by values which are at first rapidly increasing, then remain stationary, and at the beginning of dawn are slowly decreasing. The decline of the curve in the above figure between about 9:22 p. m. and 9:32 p. m. is surely due to the smoke rising from a neighboring building, and the following second decline is probably due to the same cause. The accuracy of this method of measurement may be inferred thereby.

While in this way the doubts about the existing radiation of wave lengths greater than 15 μ, which until now have not been measured may be removed by an instrument similar to Tulipan, at least as far as the nocturnal service of the instrument is concerned (I already pointed out the reasons which make its use impossible by day [4]), it is certain that the determination of the variations in the ozone content of the atmosphere remains a very difficult problem. The ultra-violet continuous spectograph which Zeiss constructed at my request[3] shows in the ultra-violet the absorption lines very clearly (the reproduction on page 15 is unfortunately not good), and it seems unquestionable that with a greater dispersion the breadth of the lines and their brightness contrast will offer an accurate means of obtaining the ozone content, though the numerous absorption lines in the ultra-violet arising from other elements will always render the problem a rather difficult one. With sufficient instrumental auxiliaries, the photoelectric intensity measurement with the cadium cell in the spectrally decomposed ultra-violet would furnish the necessary control and supplement, and it promises full success. For five years I have had very satisfactory results with the effect of the total ultra-violet sun radiation below 0.366μ on this cell.

I make use of the present occasion, in discussing the ozone effect to draw, with all due reserve, attention to the fact that according to the investigations made by J. Maurer and myself on the geographical extent of the Katmai disturbance,[7] and which I continued by my comprehensive measurements of polarization and brightness of the sky[4] and supplemented by my observations on twilight and ring phenomena[8] during the years 1912–1914

[5] *Meteorologische Zeitschrift*, 1919, p. 45.
[6] *Smithsonian Miscellaneous Collections*, Vol. 65, No. 3, 1915. *Meteorologische Zeitschrift*, 1916, p. 534.

[7] *Meteorologische Zeitschrift*, Meteorologische Zeitschrift, 1914, p. 49.
[8] *Abhandlungen des Preuss. Meteorolog. Inst.* Bd. V, No. 5, 1917.

on the gradual decreasing of the disturbance, there exists the probability that at the time of A. Ångström's measurements in California (August/September, 1913)[8] there were also dust masses prevailing in the higher atmospheric strata. Considering the great theoetical importance Ångström's final results have for the understanding of the radiation of the highest atmospheric strata[9] and, what is of more immediate interest, for their ozone content, depending undoubtedly on the degree of sun's activity, new measurements in optically undisturbed times will be needed.

I may be allowed to point out another fact: If A. Ångström's new actinometer for sky radiation[10] proves useful and magnesium oxide really very well absorbs the wave lengths greater than 4μ, then the necessary means to shelter the Stevenson shelter against radiation influence would be found. Long series of observations not yet published have proved how much the shelter needs this protection in a genuine radiation climate like that of Davos, where intense radiation is combined with low air temperature. The following unpublished figures will show that in these conditions of radiation color offers but little protection to the raw material beneath it. The experiments were made in the period from October, 1913, to January, 1914 (that is to say, low sun altitude), with hollow boxes of wood of cylindrical shape 3 cm. high and 2 cm. in diameter set up in a place entirely protected against reflected radiation and wind and free on all sides. They were filled with mercury to a level where the sun's rays could not strike the surface. In this mercury the thermometer bulb was freely suspended. The boxes were painted in the following colors: White, pink, yellow, red, and black. The result obtained was as follows. The addition of a calorie of radiating heat produced the following rise of temperature:

	°C.
White	10.8
Pink	11.0
Yellow	14.8
Red	15.7
Black	16.9

What is remarkable in this is the fact that wood remains a great heat collector also when it is painted with best reflecting white color, and that the color does not have so great an effect as is generally believed; for the dark color only adds 6° to the 11° temperature increase which the wood undergoes under the white paint. It is therefore more important that the material of the building be well chosen than the color. When absolute calm prevails, the temperature of the air is not of great influence during this one-sided insolation, but with the air in movement loss of heat sets in through conduction, and 30 per cent of the irradiating heat (roughly speaking) is lost when the air movement is slight, and 60 per cent when the movement is of mean degree. With the more strongly absorbing dark colors this loss is noticeably slower than with the light ones. If, on the other hand, reflex radiation from light walls of the neighborhood intervene, the unchanged free exposure being continued, that is to say, the box of wood being on all sides washed by the air the heat increase of the dark colors amounts to one-third, that of the lighter ones to one-fifth. If the increase of heat radiation ceases at sunset, the temperature of the dark colors decreases quicker, according to their greater surplus over the temperature of the ambiant air, especially for the first 10 minutes; after 20 minutes the temperature of the dark colors exceeds that of the air about 3½° against 3½° for the lighter colors; after 40 minutes about 2° against 1°. The loss of heat is very slow as may be seen.

Finally, an exceedingly ingenious test for the investigations in infrared may be mentioned; that is, the use of bacteria which react very keenly at spectrum line's breadth. These can be advantageously substituted for the photographic plate more or less satisfactorily in this part of the spectrum.

[9] *Smithsonian Miscellaneous Collection loc. cit.* Hergesell, *Abhandl. Aeronaut. Observ. Lindenburg*, Bd. XIII, 1919.

[10] MONTHLY WEATHER REVIEW, 1919, 47: p. 795.

A WATERSPOUT IN THE ADIRONDACKS.

The United States Weather Bureau meteorologist at Albany, N. Y., Mr. George T. Todd, has reported an interesting and unusual waterspout which was observed on Lake Newcomb in the Adirondack Mountains. On the afternoon of May 16, Mr. F. W. Kelly, of Albany, and several others observed a whirl of water which appeared to be a partly formed waterspout. The column of water was about 4 feet in height and about as large in diameter as a flour barrel. It moved across the lake from northwest to southeast, whirling counterclockwise. There appeared to be no unusual atmospheric disturbance on shore before the waterspout started, but, beginning where the water was about a foot deep and progressing across the lake where a depth of 3 or 4 feet, the spout ended with a considerable splash on the opposite shore. A depression in the water level near the spout was also observed. The center of the whirl passed within 20 to 25 feet of Mr. Kelly, but no unusual atmospheric condition was noticeable. He said there was a sound of rushing water similar to that made by turning the water from a high pressure fire hose on another body of water.—*C. L. M.*

TORNADO IN UNION COUNTY, N. C., JUNE 20, 1920.

At 2 p. m. of June 20 a tornado of considerable violence formed in the southwestern part of Union County, approximately 22 miles south-southeast of Charlotte, seriously injuring one person, demolishing eight dwellings and a number of barns and outbuildings, and inflicting considerable damage to cotton fields, crops, and timber. The total damage is estimated at about $30,000.

The storm apparently began a short distance south of the village of Waxhaw and ended at or near Wesleys Chapel, having followed a northeasterly path about 7½ miles long and about 200 feet wide.

It is possible that the inception of this tornado was witnessed by Mr. and Mrs. Rock Morrison, who were traveling by automobile from Miami, Fla., to Charlotte. At 2 p. m. of the above date they stopped at the Osceola Creek bridge to adjust a tire, and their experiences there are reported in the Charlotte News as follows:

"While the automobile was standing, Mrs. Morrison observed a small whirlwind stirring up the leaves on the top of a small hillock about a quarter of a mile away. It dipped toward the surface of the ground for a moment and appeared to lift a few feet above the surface for a moment. This was indicated by the leaves and stubble once picked up fluttering back to earth. Presently, however, there was a noticeable quantity of leaves and stubble flying in the air, and Mrs. Morrison directed her husband's attention to it.

"In a moment the tiny whirlwind had resolved itself into a swirling tornado, which became black with leaves, sticks, twigs, and limbs of trees and débris of various kinds, as it started a rapid sweep across the landscape with an ominous roar.

"Awestruck at the unusual sight, Mr. and Mrs. Morrison watched the cloud, which was clearly funnel-shaped, sweep over the country and pick up a house which it smashed, hurling bits of the shingle roof, window sash and other bits of wood high in the air. It twisted trees into tooth brushes of colossal size, and cut a swath through the forest and over fields as distinct as if some giant with a scythe had